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Particle sedimentation patterns in the eastern Fram Strait during 2000–2005: Results from the Arctic long-term observatory HAUSGARTEN

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ABSTRACT

Since 2000 long-term measurements of vertical particle flux have been performed with moored sediment traps at the long-term observatory HAUSGARTEN in the eastern Fram Strait (79°N/4°E). The study area, which is seasonally covered with ice, is located in the confluence zone of the northward flowing warm saline Atlantic water with cold, low salinity water masses of Arctic origin. Current projections suggest that this area is particularly vulnerable to global warming. Total matter fluxes and components thereof (carbonate, particulate organic carbon and nitrogen, biogenic silica, biomarkers) revealed a bimodal seasonal pattern showing elevated sedimentation rates during May/June and August/September. Annual total matter flux (dry weight, DW) at ~300 m depth varied between 13 and 32 $g\,m^{-2}\,a^{-1}$ during 2000 and 2005. Of this total flux 6–13% was due to $CaCO_3$, 4–21% to refractory particulate organic carbon (POC), and 3–8% to biogenic particulate silica (bPSi). The annual flux of all biogenic components together was almost constant during the period studied (8.5–8.8 $g\,m^{-2}\,a^{-1}$), although this varied from 27% to 67% of the total annual flux. The fraction was lowest in a year characterized by the longest duration of ice coverage (91 and 70 days for the calendar year and summer season, May–September, respectively). Biomarker analyses revealed that organic matter originating from marine sources was present in excess of terrigenious material in the sedimented matter throughout most of the study period. Fluxes of recognizable phyto- and protozooplankton cells amounted up to $60 \times 10^6\,m^{-2}\,d^{-1}$. Diatoms and coccolithophorids were the most abundant organisms. Diatoms, mainly pennate species, dominated during the first years of the investigation. A shift in the composition occurred during the last year when numbers of diatoms declined considerably, leading to a dominance of coccolithoporids. This was also reflected in a decrease in the sedimentation of bPSi. The sedimentation of biogenic matter, however, did not differ from the amount observed during the previous years. Among the larger organisms, pteropods at times contributed significantly to both the total matter and $CaCO_3$, fluxes.

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1. Introduction

The Arctic Ocean, one of the regions most sensitive to climatic changes, has received increasing attention recently because of the drastic decrease of sea ice cover and extent (e.g., Maslanik et al., 2007; Comiso et al., 2008). These changes in the physical environment will eventually have enormous consequences for the pelagic system, as well as for the export of organic matter from the productive layer to the deep sea (Thingstad et al., 2008). Knowledge of this export is fundamental to our understanding of the global carbon cycle. Long-term investigations are a prerequisite to our understanding of the concomitant changes in sea surface temperatures, in sea ice and in the pelagic realm.

The downward flux of particulate matter and the inter-annual and seasonal variability in the amount and composition of the particles can provide indirect insight into the pelagic system above. Sediment traps are the only particle collectors capable of measuring the direct downward flux of particles (Zeitzschel et al., 1978; Asper, 1987; Kremling et al., 1996). As far as we know, however, only a few long-term observations exist in the deep Arctic Ocean because of its inaccessibility and logistic constraints. Studies of particle flux for 1 year or longer have only been done on few occasions (Honjo, 1990; Hebbeln and Wefer, 1991; Hargrave et al., 1994; Zernova et al., 2000; Peinert et al., 2001; Michel et al., 2002; Fahl and Nöthig, 2007). Most other studies were restricted to subarctic or shelf areas (e.g., Takahashi et al., 2000; Wassmann et al., 2004). Long-term observations using sediment trap moorings can thus provide a better understanding of pelagic processes in times of the changing climate. They are particularly suited to following the changes in ecosystem structure over longer periods of time and to possibly predicting future trends and consequences, e.g. for carbon fluxes in the ocean.

The use of sediment traps and the validity of results obtained by these devices has been a matter of debate for more than 20 years over hydrodynamical biases and trapping efficiency (Butman, 1986; Gust et al. 1994; Gardner, 1999; Scholten et al., 2001). Buesseler et al. (2007) recently reviewed problems related to the use of sediment traps in the upper ocean. Despite the uncertainties specified in this review, which one has to bear in mind when dealing with sediment trap data, we are confident that sediment traps provide an appropriate tool to gain insights in downward particle flux patterns throughout the year. They are independent of shiptime and weather conditions, and at present, they are the only tools that allow the continuous collection of sinking particles for further analyses over longer periods of time.

Here we present the results from the first 5 years of investigation from the central station of the HAUSGARTEN deep-sea observatory. This long-term observatory, established by the Alfred-Wegener Institute for Polar and Marine Research (AWI) in 1999, is located in the eastern Fram Strait between 78°30′ and 80°00′N and between 3° and 7°E, ca. 120 km west of Spitsbergen (Fig. 1). It comprises water depths from 5000 to 1300 m (for details see Soltwedel et al., 2005). Sediment traps have been deployed 250–300 m below the water surface and 150 m above the sea floor every year since 2000. The longest time series on sedimentation was obtained from the uppermost traps, and thus we concentrate on these results to present seasonal and inter-annual changes in flux pattern and composition of settling matter.

In this study we use sediment traps as a remote sensing tool to gain insights into seasonal succession within the upper pelagic realm. This enables us to gain perspective on growing and resting phases as well as the respective particle fluxes of the pelagic system even in ice-covered or temporarily ice-covered environments. The results obtained during the first years of the study may also serve as a baseline against which to monitor expected changes in the pelagic environment in this vulnerable region of the ocean.

In general, the Arctic Ocean, including the HAUSGARTEN area, is less productive than other oceans because of the permanent icecover and the extreme seasonal variability of irradiation. Data presented in this manuscript are available in the database PANGAEA (http://doi.pangaea.de/10.1594/PANGAEA.714845).

2. Hydrographic regime at the HAUSGARTEN

The particle flux in this region is influenced by sea ice and hydrographic conditions. In the eastern Fram Strait, warm and saline water of Atlantic origin is transported to the north with the West Spitsbergen Current (WSC), whereas in the western Fram Strait the East Greenland Current (EGC) carries less saline and cold polar water masses (PW) to the south in the upper layer. The Arctic Front (AF), separating the warm and cold water masses, is located within the investigation area at 4–6°E (Hop et al., 2006), thus involving the influence of both Atlantic and Polar water masses on the inhabiting organisms.

The northward flowing WSC has its core at the shelf slope off Spitsbergen. The Atlantic water (AW) masses are confined to the upper 700 m at the latitude of the sediment trap moorings. The strength of the AW inflow varies with the seasons, inter-annually and over longer time periods. Long-term fluctuations may be related to the North Atlantic Oscillation (NAO) (e.g., Saloranta and Haugan, 2001, 2004; Schauer et al., 2004), which also correlates well with variations in the sea ice extent in the Nordic Seas (Vinje, 2001; Divine and Dick, 2006).

Local circulation patterns and hydrographic conditions were inferred from long-term measurements at a moored array at 78°50′N (for details see Fahrbach et al., 2001; Schauer et al., 2004, 2008). Even though the line of moorings is located ca. 20 km to the south of the position of the sediment traps, the mean currents observed there are representative for the flow pattern in the area.

The complex bathymetry including a system of ridges, deeps and seamounts (Fig. 1) strongly affects the currents in the area. A part of the inflowing AW recirculates immediately in the Fram Strait along different pathways, because of the strong topographic steering (Bourke et al., 1987; Gascard et al., 1995; Walczowski et al., 2005). This